Indian Ocean METOC Imager

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IOMI Operational Concept
Demonstrates Military Operational Utility
and Enables Improved Global Weather Prediction

LONG-TERM GOALS

Using advanced technologies, the Indian Ocean METOC Imager (IOMI) Program will develop and launch a geostationary imager to demonstrate over the Indian Ocean the military operational utility of an advanced weather sensor. A partnership with NASA has been formed to utilize the New Millenium Program, Earth Observing 3 Geostationary Imaging Fourier Transform Spectrometer (GIFTS) sensor development to provide this advanced capability. The IOMI program will share costs for the GIFTS sensor development, the spacecraft bus, provide lifetime enhancements to the GIFTS sensor, and

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extend the mission life to provide a validation period of the technologies over the Indian Ocean. Direct data downlink to the Fleet via SMQ-11 will demonstrate the operational military utility in addition to data distribution to Navy centers, NOAA, NASA and the Australian Bureau of Meteorology community. Additionally, GIFTS will provide Federal Aviation Administration and Air Force Weather Service forecast of Turbulence & Convective Instability for commercial airplanes/air traffic during the CONUS demonstration and calibration/validation phase. Demonstration of real-time temperature and moisture field will enable the nowcasting (i.e., observation and short-term forecasting) demonstration of changing weather and cloud conditions, as needed for military enroute tactical decisions during aircraft operations. The National Oceanic and Atmospheric Administration (NOAA) will participate in the NASA/Navy program by providing the CONUS Phase I ground station infrastructure and data calibration/validation. The Australia Bureau of Meteorology has expressed their intent to provide a ground station and data processing during the Phase II, DoD Mission over the Indian Ocean, to facilitate the distribution of data to the World Meteorological Community for enhanced global weather models.

OBJECTIVES

The primary objective of the IOMI program is to provide direct data downlink of high resolution visible and IR imagery to Navy ships in a tactically significant area of interest that currently has no reliable DoD coverage. The IOMI will demonstrate multi-mission battlespace characterization through analysis of synpotic-scale weather patterns, detecting and monitoring of severe storm conditions, providing precipitation estimates, classifying clouds, and computation of cloud drift winds. NASA's GIFTS sensor satisfies the Navy requirement with some modifications to lifetime and orbit re-location. The GIFTS NMP objective is to demonstrate revolutionary science and enabling technologies with a one year CONUS technology demonstration program. The Navy partnership will increase the lifetime of the sensor and increase the technology demonstration to a 5-7 year mission over the IO (FY06-13) after the ~ 1 year CONUS NMP mission. The GIFTS/IOMI mission will be instrumental in filling a large weather data void with the potential to greatly improve global weather forecasting.

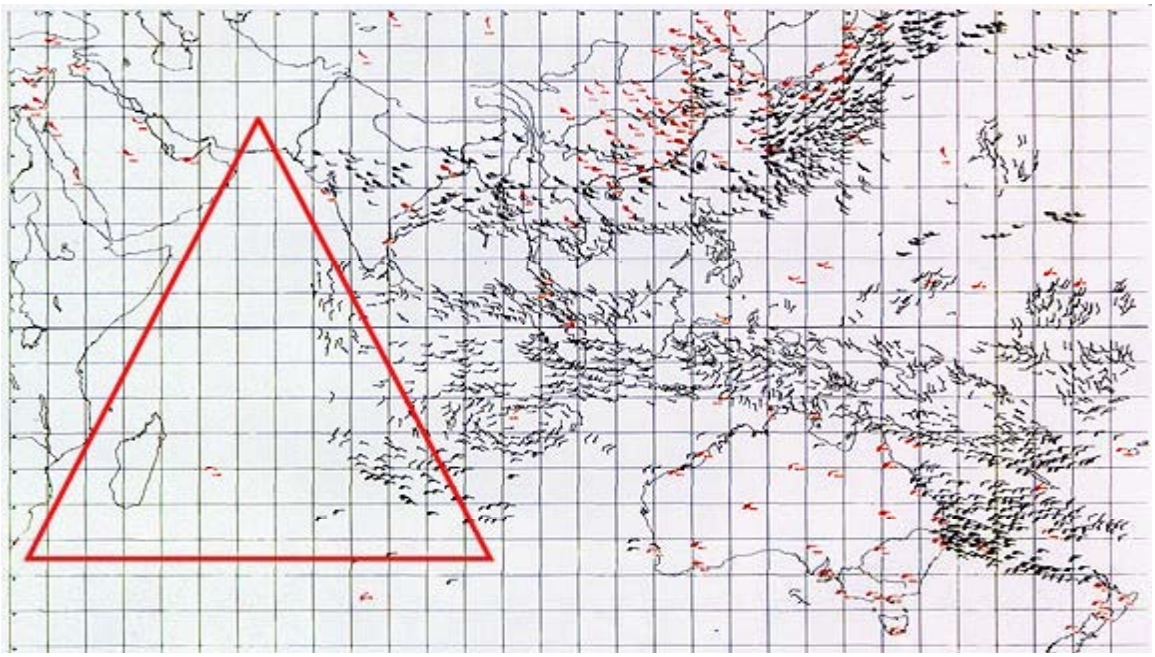

Figure 1. Current Indian Ocean Available Weather Data

APPROACH

GIFTS is a high spectral resolution IR imaging Fourier Transform Spectrometer and visible imager. IOMI/GIFTS will use advanced technologies including cyrogenic Michelson interferometer and metrology laser, large area format focal plane array, miniaturized cryocoolers for active cooling, on-board high speed analog to digital processing, radiation hardened vector processors for real-time signal processing and data compression, automomous pointing and control for precise image stabilization and feature tracking, ultra-low power radiation tolerant microelectronics and lightweight structures and optics to minimize instrument mass. The sensor will be integrated with required communications subsystems on a TRW 310 geosynchronous spacecraft bus. The TRW 310 is the follow-on to the TRW 300 bus currently on orbit for a national customer. The existing design of the TRW 310 has weight and power available for approximately 2 additional payloads.

The IOMI/GIFTS sensor will demonstrate revolutionary hyperspectral atmospheric characterization by making altitude resolved "water vapor" winds measurements from a geostationary orbit. The instument will observe temperature, water vapor, and tracer wind profiles with high vertical, horizontal, and temporal resolution; observe vertical profiles and transport of radiatively active trace gases including H2O, CO utilizing a revolutionary sounding capability. IOMI/GIFTS will demonstrate the military operational utility using on-board high performance processing and data compression to provide the tactical real-time downlink via SMQ-11.

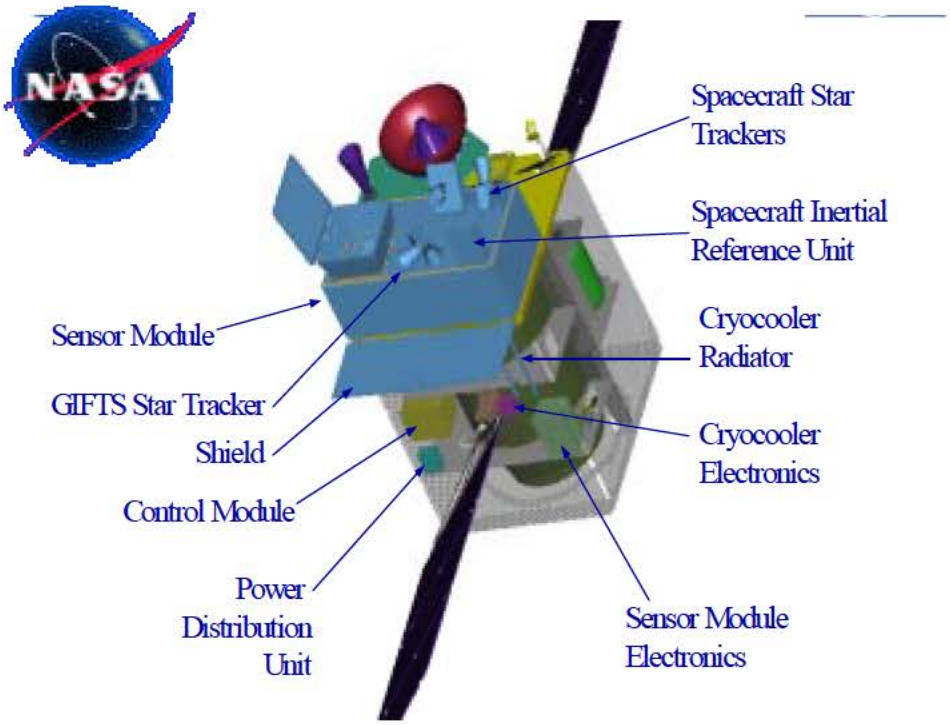

Figure 2. NASA New Millenium Program EO-3, GIFTS Instrument

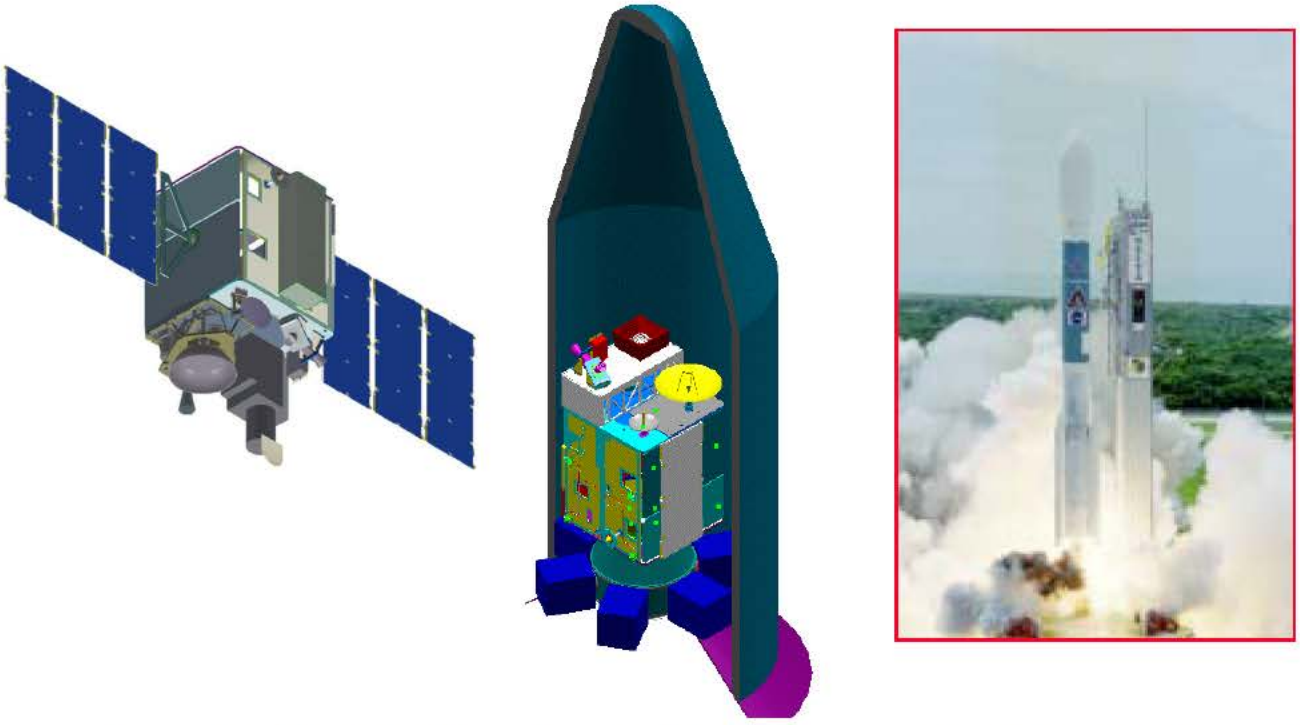

Figure 3. IOMI-GIFTS Mounted on the TRW 310 Spacecraft With Solar Cells Deployed; Launch Configuration with MLV-05 Mission ESPA Ring for Secondary Payloads on a Delta Launch Vehicle

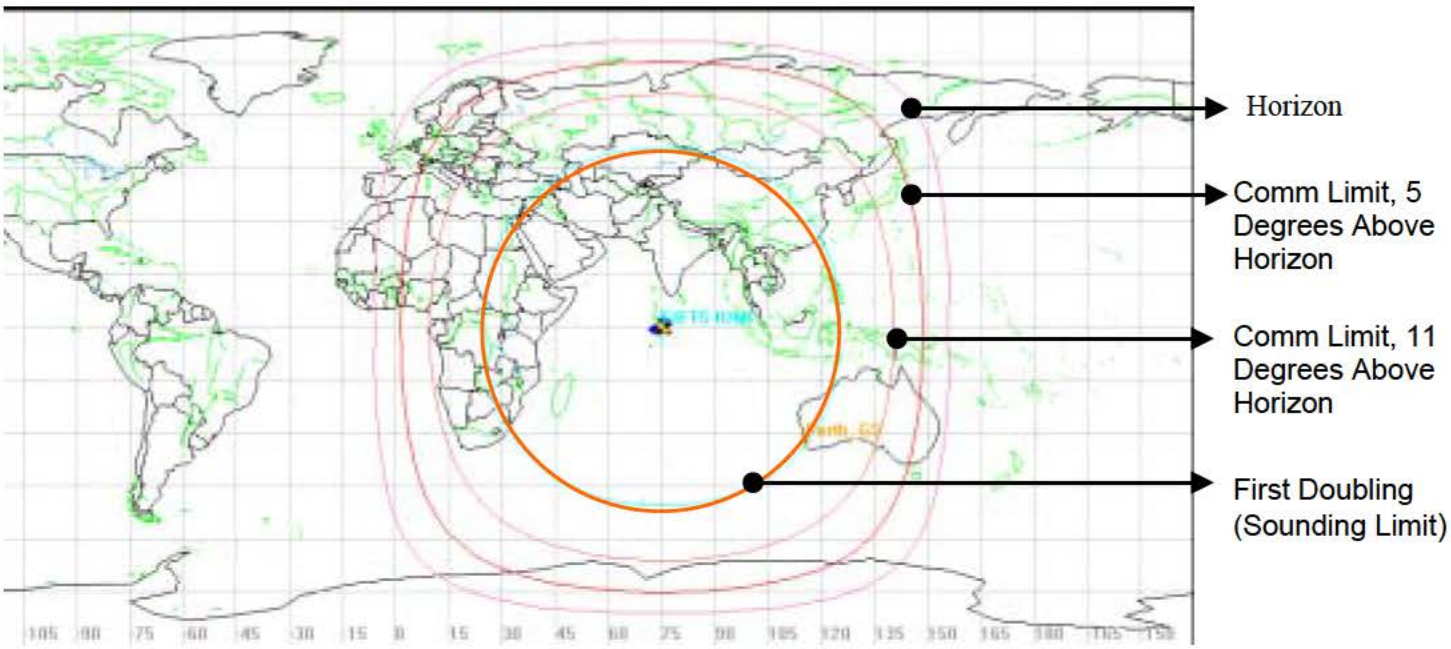

Figure 4. IOMI will be located at 75ºE

WORK COMPLETED

NOAA joined the inter-agency partnership as a result of the Navy lifetime enhancements to the GIFTS sensor and will utilize the IOM-/GIFTS project as risk reduction for the NOAA GOES Advanced Baseline Sounder program. The interagency Memorandum of Agreement (MOA) to develop the GIFTS-IOMI sensor jointly was executed by Navy, NASA and NOAA in July 2002. ONR successfully competed the IOMI-GIFTS project in the DoD Space Experiments Review Board (SERB) competition and was ranked #1 by both the Navy and the Department of Defense SERB Boards. Subsequently, ONR and the DoD Space Test Program executed an MOA for access to space in July, 2002, for the IOMI-GIFTS (ONR-0001) experiment, the IMAGE (NRL-506) experiment and the MGAS (ONR-0101) experiment on the STP MLV-05 mission scheduled for launch in March 2006. The spacecraft contract with TRW is in place with the DoD Defense Micro Electronics Activity for the multi-mission payload complement. The GIFTS System Requirements Review and Preliminary Design Review have been successfully completed and the Navy requirements for additional lifetime enhancements have been incorporated into the design development.

RESULTS

Navy partnership in the NASA EO-3 program will increase the lifetime of the GIFTS sensor from a 12-18 month CONUS demonstration, described as Phase I in the interagency MOA, to an additional >5 year technology demonstration over the Indian Ocean, described as the Phase II DoD Indian Ocean Mission in the MOA, while providing imagery data directly to the Fleet. This extended lifetime will enable the demonstration of critical sensor technologies for future civil and military weather systems while filling a large weather data void in the Indian Ocean to greatly improve global weather forecasting.

IMPACT/APPLICATIONS

IOMI/GIFTS will provide a unique moisture flux and wind profile measurement capability through the combination of three technologies which enable four dimensional (x,y,z,t) measurements of atmospheric state parameters in the Indian Ocean which is a tactically significant area of interest that currently has no reliable coverage. The horizontal dimension (x,y) is provided by the use of Large area format Focal Plane Arrays (LFPA) similar to that provided by a digital camara. The incoming light is passed through a Fourier Transform Spectrometer (FTS), before reaching the LFPA , which provides the vertical dimension (z) to the digital imagery. With the imaging FTS mounted on a geostationary satellite, the three dimensional atmospheric state is observed as a function of time (t) thereby enabling atmospheric dynamics, including air parcel motion, to be measured.

GIFTS differs from contemporary geostationary satellite imaging and sounding systems in that it employs an FTS which provides thousands of high resolution spectral channels of information as opposed to the few low resolution spectral channels of information provided by conventional filter radiometer systems. The high spectral resolution and large number of spectral channels enables high contrast imagery of selectable surface and atmospheric features and high vertical resolution atmospheric soundings, including wind soundings, unachievable with contemporary devices. Also, unlike currently operational systems, GIFTS performs the imaging and sounding functions of a geostationary satellite observing system simultaneously using a single instrument.

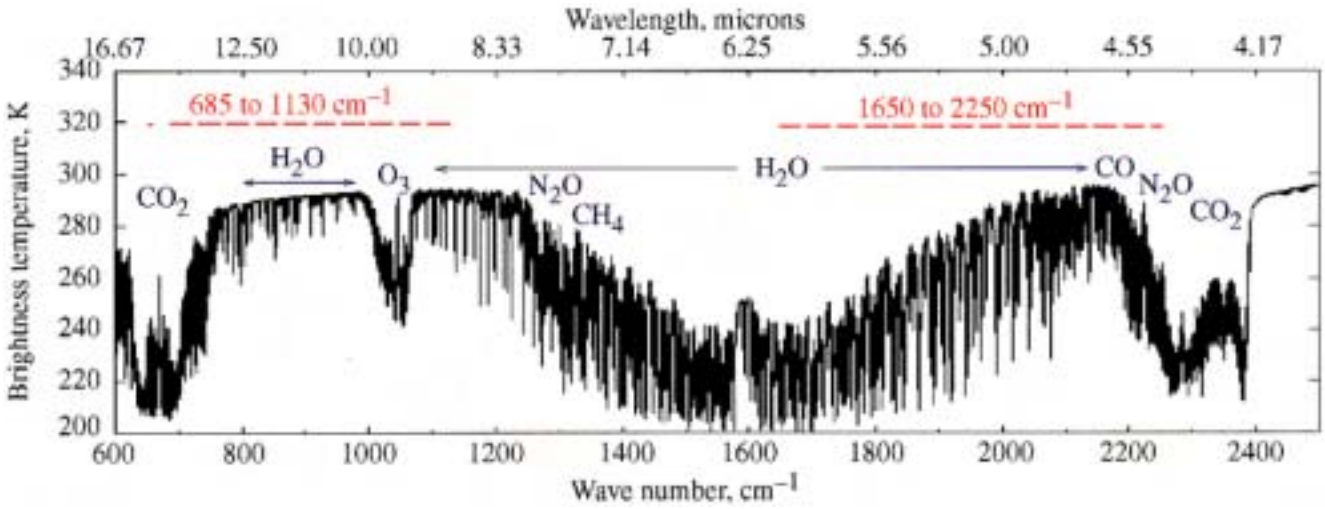

Figure 5. GIFTS Spectral Coverage

TRANSITIONS

NOAA is participating in the IOMI-GIFTS program by providing the CONUS ground station and ground station infrastructure and the calibration and validation of the data while over CONUS (CY06). Additionally the GIFTS technology development and science measurement concept will transition to the development of the Next Generation GOES sensors, the Advanced Baseline Sounder. The GIFTS

demonstrated technology will serve as an important step toward the infusion of new technology into the future international system of operational geosynchronous satellites as needed to achieve scientific quality atmospheric state products on a routine and long-term basis. The Large Focal Plane Array (LFPA) component will provide the nearly continuous observation of large geographical areas with high horizontal resolution. The Fourier Transform Spectrometer (FTS) component will enable the simultaneous measurement of infrared radiation spectra by each detector element with a spectral resolution sufficient for resolving the structure of the atmosphere with high vertical resolution.

Concomitant with the FTS and LFPA technologies are the data readout and processing electronics; lightweight structures and optics; radiation shielding; precision pointing and control; and an ultra-stable metrology source. While technology development funds for the past three years have advanced these technologies to their current readiness levels, the long-term effects of the space environment on the detectors, composite materials, etc., require the rigor of spaceflight to provide their validation and risk assessment as they might apply to operational systems.

Future military weather systems will greatly benefit from the demonstration of these technologies. Additionally, civil satellites with these advanced capabilities will provide valuable weather support to military units operating within view of the Next Generation GOES satellites.

RELATED PROJECTS

1) NASA, Earth Observing 3 Program, New Millenium Program Office:

GIFTS temperature, moisture, and wind profiling capability has been demonstrated experimentally using airborne instruments (i.e., NAST-I and HIS) which have spectral radiance measurement capabilities similar to the GIFTS. Atmospheric motions have been demonstrated with NAST-I retrievals from radiance measurements. The NAST-I has a spatial resolution of 2.5 km and a spectral resolution of 0.25 cm-1 over a spectral range from 3.5 to 16 microns. Temperature and moisture retrievals are obtained at the full resolution of the data. Using NAST-I, it has been demonstrated that high spatial resolution retrievals of temperature and water vapor at half-hourly intervals from GIFTS/IOMI would provide observations of water vapor flux and wind profile information. In this case, an animated set of half-hourly interval images of water vapor (in terms of mixing ratio and relative humidity) are derived from a time series of NAST-I profile retrievals from spectral radiance observations over a small area near Andros Island, Bahamas. These animations show that the water vapor flux can be observed. The flow is seen to change direction with altitude. These experimental results, which imply a strong vertical shear in wind direction, indicate that vertical profile information about the wind velocity can be achieved by observing the displacement of water vapor features at different atmospheric levels, a unique element of the GIFTS measurement concept proposed.

Another impressive aircraft observation example results from an analysis (East/West Animation / North/South Animation) of High resolution Interferometer Sounder (HIS) data obtained at Wallops Island, VA. Both HIS and GOES-8 sounding data were assimilated into a 10 km spatial resolution mesoscale NWP model. The aircraft and GOES observations covered a 75-km x 75-km grid, with 10 km spacing, and were repeated each hour over a six-hour period. It can be seen that the high vertical resolution HIS soundings revealed the cellular motions associated with the land breeze phenomena and

showed moisture features moving with the wind. Neither of these mesoscale circulation features could be resolved with the lower vertical resolution GOES-8 sounding data.

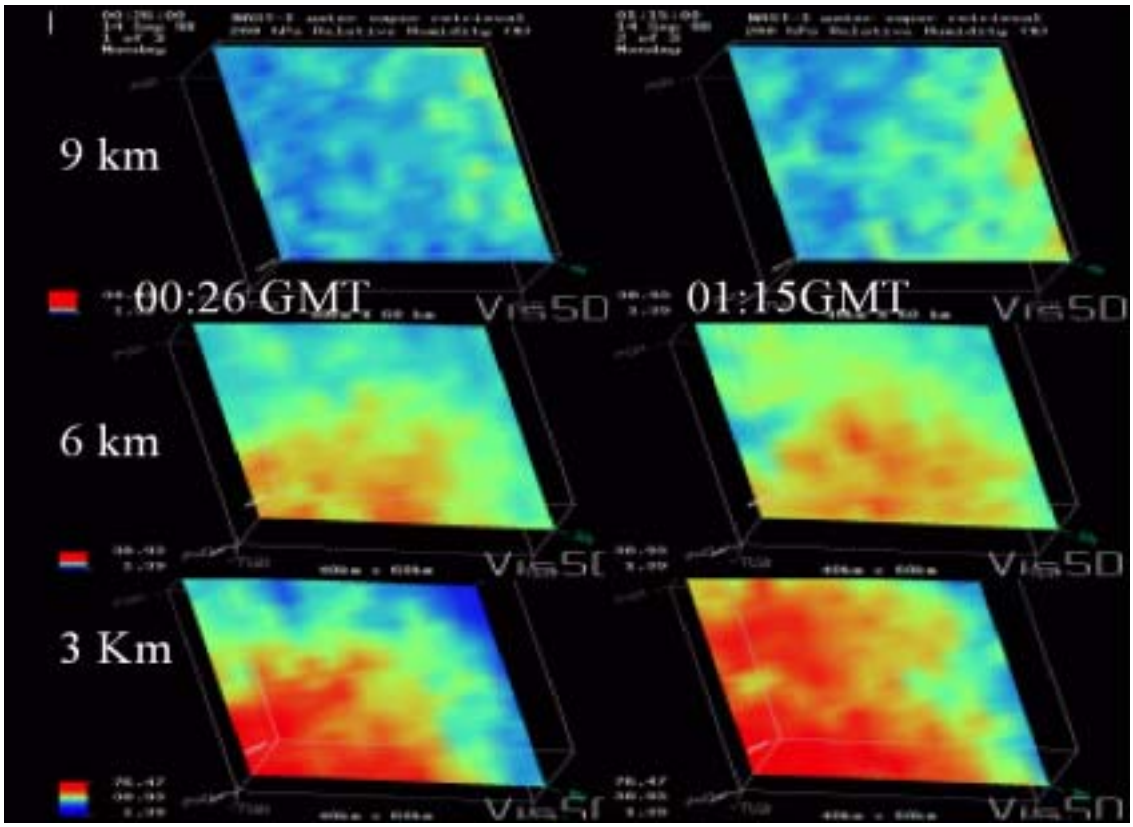

Figure 6. NAST-I Demonstration of GIFTS Wind Profiling Capability

2) DoD Space Test Program:

The MLV-05 Program Office of the DoD Space Test Program is providing the access to space for the IOMI-GIFTS, IMAGE and MGAS payloads utilizing a Delta IV class launch vehicle. The MLV-05 program consists of approximately 10-11 additional payloads from the DoD Space Experiments Review Board ranking list. In August 2002, the STP contracted with Boeing to provide the launch vehicle integration for the mission.

3) University of Wisconsin-Madison:

The University of Wisconsin-Madison (UW), Principal Investigator Professor Allen Huang, has been awarded a grant, under the Multiple University Research Initiative (MURI) funded by DDR&E for IOMI modeling, processing and algorithm development. The UW MURI research will be performed from 2002-2006. Data from IOMI-GIFTS, once launched in 2006, will offer the DoD unprecedented opportunities to characterize the physical and chemical properties of the atmosphere and surface in great detail to support its defense missions in hyperspectral research such as a) numerical weather prediction model runs, b) IOMI measurement simulation, c) IOMI hyperspectral modeling analysis, d) retrieval of atmospheric thermal dynamical variables and e) wind information derivation.

The outcome of this work will not only maximize the current investment of DoD but will also enable an optimized real-time centralized and/or shipboard system processing of IOMI data to support DoD strategic objectives. This research offers a step in weather and surface property characterizations (with applications for battlespace environment characterization) comparable to the step made by the first spin-scan camera or the first geostationary sounding instrument, both originating from efforts at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and the Space Science and Engineering Center (SSEC) of the University of Wisconsin-Madison.

The key goals of this effort are:

1) To translate optimally, as well as efficiently, the physical principles of a hyperspectral data retrieval problem to the mathematical algorithms that try to solve it.

2) To quantify mathematically where the useful information to complete a physically-driven application resides in the electromagnetic spectrum

3) To enhance the applications of physics-based processing of hyperspectral data for surface material detection, classification and identification; atmospheric parameter retrieval and coastal water quality.

The CIMSS/SSEC of University of Wisconsin-Madison has pioneered not only new remote sensing approaches and analysis techniques, but also has built processing hardware systems to process TOVS; currently utilized on NOAA polar orbiting satellites, VAS, current GOES (imaging and sounding data from a geostationary platform) and more recently MODIS, the Terra polar orbiting satellite for direct broadcast data.

CIMSS/SSEC of UW has over 25 years of experience in the processing of infrared spectral data for the characterization of weather and atmospheric chemistry, as well as for the detection, classification and identification of land-surface materials. Several end-to-end data ingesting, analysis, and archiving systems have been successfully deployed for many years in the High-resolution Interferometer Sounder (HIS), Atmospheric Emitted Radiance Interferometer (AERI), and Scanning HIS (S-HIS) programs of UW-Madison (Revercomb et al. 1988; Smith et al. 1990; Revercomb et al. 1993; Minnett et al. 2000).

4) The Ionospheric Mapping and Geocoronal Experiment (IMAGE):

The IMAGE space weather experiment, sponsored by the Office of Naval Research and being developed by the Naval Research Laboratory, (NRL-506) monitors the earth's ionosphere from a geo-synchronous orbit. The objective is to track regions of ionospheric irregularities such as Spread-F and scintillation (which cause fading and dropouts of frequencies up to and including GPS); and to determine total electron content, maximum ionospheric height (Hmax), and ionospheric tilts (which determine radio propagation).

5) Military Global Positioning System (GPS) Augmentation System (MGAS):

MGAS is an FY03 Advanced Concept Technology Demonstration (ACTD) which will demonstrate, through the use of a geo-synchronous, high power L-band transponder and leveraging existing

architectures, a sensor-to-weapon data link which will permit targeting data updates, multiple secure message channels, and reduce the possibility of target area GPS jamming by providing a greater signal power in theater. The basic goals of the MGAS program are:

1) Improved Accuracy - Increases in GPS Location Accuracy for Platforms, Sensors and Munitions;

2) Improved Anti-Jamming - Timing and Navigation;

3) Increased Navigation Messaging In Near Real Time (2 Second Latency) - Multiple Potential Applications; Sensor-To-Weapon Messaging Protocols; Integrity Messages and Alternative Differential Protocols and

4) Space-Based Transponder to Demonstrate Next Generation Modulation Techniques, Navigation Messages and Higher Power Signals – Supports Risk Reduction Activities for GPS III, GEO/MEO Mix Issues. This program will provide an Initial Operational Capability (IOC) of a Digital Fires Network (DFN) by fiscal year 2006.